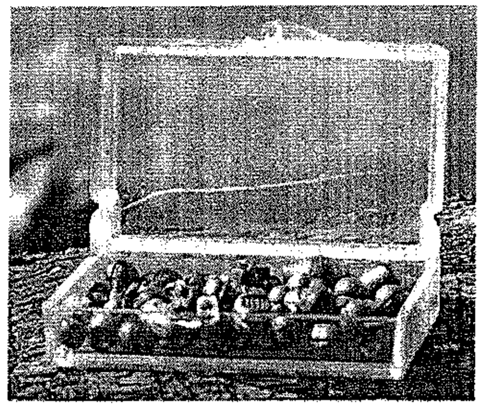
FEATURE:
FISHERIES MANAGEMENT



Management Concerns about Known and Potential Impacts of Lead Use in Shooting and in Fishing Activities

ABSTRACT: We present a summary of the technical review, jointly requested by the American Fisheries Society and The Wildlife Society, addressing the hazards to wildlife resulting from lead objects or fragments introduced into aquatic and terrestrial environments from the use of ammunition and fishing tackle. Impacts from lead are well documented in humans, as well as in terrestrial and aquatic organisms. Concern about impacts from lead ammunition and fishing tackle has resulted in the development of non-lead alternatives, educational campaigns, and regulations to restrict their use. This article discusses the general biological impacts of lead exposure from fishing and shooting activities to fish, wildlife, and humans; summarizes existing and proposed regulations to reduce lead exposure to biota; reviews alternatives to lead materials that are currently available for fishing; and outlines options for further actions to reduce wildlife and human exposure to lead from fishing activities.

Chris I. Goddard,
Nancy J. Leonard,
Doug L. Stang,
P. Jack Wingate,
Barnett A. Rattner,
J. Christian Franson, and
Steven R. Sheffield

Goddard is the executive secretary of the Great Lakes Fishery Commission at the Great Lakes Fishery Commission, Ann Arbor, Michigan, and can be contacted at cgoddard@glfc.org. Leonard is an academic specialist at the Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing. Stang is assistant director at the Bureau of Fisheries, New York State Department of Environmental Conservation, Albany. Wingate is a fisheries research manager who is retired from the Minnesota Department of Natural Resources, St. Paul. Rattner is an ecotoxicologist at the Patuxent Wildlife Research Center, Beltsville Laboratory, U.S. Geological Survey, Beltsville, Maryland. Franson is a research wildlife biologist at the National Wildlife Health Center, U.S. Geological Survey, Madison, Wisconsin. Sheffield is a professor at the Department of Natural Sciences, Bowie State University, Bowie, Maryland and at the National Capital Region—Northern Virginia Center of the College of Natural Resources, Virginia Polytechnic Institute and State University, Falls Church.

Previsiones de Manejo Acerca de Impactos Conocidos y Potenciales del Uso de Plomo en Actividades de Caza y Pesca

RESUMEN: Presentamos un resumen de la opinión técnica solicitada por la Sociedad Americana de Pesquerías y la Sociedad para la Vida Silvestre con respecto a los peligros para la vida silvestre que resultan de la introducción de objetos o fragmentos de plomo a los ambientes acuáticos y terrestres, provenientes del uso de municiones y equipos de pesca. El efecto del plomo está bien documentado en humanos, así como también en organismos terrestres y acuáticos. La preocupación acerca de los efectos de la presencia de plomo proveniente de municiones y equipos de pesca ha resultado en el desarrollo de diseños alternativos libres de plomo, campañas educativas y regulaciones para restringir su uso. En este artículo se discuten los impactos biológicos generales en peces, vida silvestre y humanos de la exposición al plomo derivado de la caza y pesca; se hace un resumen de las regulaciones tendientes a reducir la exposición de la biota al plomo; se hace una revisión de los materiales alternativos al plomo disponibles para las actividades de pesca, y se proponen posteriores acciones tendientes a reducir la exposición humana y de la vida silvestre al plomo producido por las actividades de pesca.

INTRODUCTION

Lead (Pb), being one of the easiest metals to mine and smelt (Pattee and Pain 2003), has been extracted and used by societies for numerous purposes at least as far back in time as the Roman Empire (Hernberg 2000). Lead can be introduced into the environment from multiple sources including surface runoff; atmospheric deposition associated with the burning of coal, oil, and waste; release of contaminated tailings from mining and smelting activities; the application of products containing lead; and through the loss of lead objects, such as lead shot and fishing weights (IPCS 1989; Henny et al. 1994; Scheuhammer and Norris 1995).

Lead is a nonessential heavy metal with no known beneficial role in biological systems. The adverse effects of lead on human health have long been recognized. Exposure of humans to lead is known to adversely affect hematopoiesis, the central and peripheral nervous systems, the renal system, cardiovascular system, and can result in brain dysfunction, neuropathy, altered amino acid transport, anemia, impaired fetal development, and reduced survival (Nordic Council of Ministers 2003; Khan 2005). Some studies have associated elevated bone or blood lead levels with aggression, delinquent behavior (Needleman 2004), and attention deficit hyperactivity disorder (Braun et al. 2006). Although the adverse effects of lead on human health have long been recognized, the exposure of fish, wildlife, and humans to lead continues (Hernberg 2000).

In comparison to the long-standing recognition of the effects of lead poisoning in humans, the hazard of lead ammunition and fishing sinkers to wildlife has only recently been acknowledged (Pattee and Pain 2003). In this article we present a summary of the technical review that was jointly requested by the American Fisheries Society and The Wildlife Society (Rattner et al. 2008). Specifically, we review briefly the effects of lead introduced by fishing and shooting activities to living organisms, discuss regulations and alternatives to lead to reduce exposure, and suggest possible actions that may further minimize lead introductions into the environment from fishing.

DISSOLUTION OF LEAD FROM SPENT AMMUNITION AND FISHING TACKLE

Spent lead ammunition and lost lead fishing tackle are not readily dissolved in aquatic and terrestrial systems and, depending on environmental conditions, can be relatively stable and remain intact for decades to centuries (SAAMI 1996). Lead from spent ammunition and tackle can undergo weathering and lead salts can dissociate, form stable complexes (carbonates, hydrides, chlorides), precipitate (phosphates, sulfides, carbonates, hydroxides), become bound to soil and sediments, and thus exist in many forms with varying degrees of bioavailability. Uptake of lead by plants is relatively limited, although several studies have documented elevated lead concentrations in plants in the vicinity of shooting ranges (Rooney et al. 1999; Hui 2002; Cao et al. 2003; also reviewed in Rattner et al. 2008). Weathering and dissolution of elemental lead is influenced by water chemistry, mechanical disturbance (e.g., water flow rate), grain size of soils and sediments, gaseous aerobic conditions, and acidity and alkalinity. Under some conditions (e.g., soft acidic waters, mechanical disturbance), lead can be released from artifacts, although annual corrosion rates of lead are generally low (Jacks and Bystrom 1995). Due to the possible dissolution of lead ammunition and fishing tackle, we review briefly the findings from studies examining the effects of bioavailable lead on living organisms, including fish, amphibians, reptiles, birds, mammals, and humans.

In field and laboratory studies, lead is generally found to evoke its toxicity in multiple organ systems. Perhaps best known are inhibition of heme-synthesis enzymes, lead-induced anemia, central and peripheral neuropathy, nephrotoxicity, hypertension, and alteration to endocrine and reproductive function. Lead is also known to be a carcinogen for some animals (Needleman 2004). Numerous studies have examined the effects of lead on fish. It is well known that bioavailable lead principally accumulates in the gills, liver, kidney, and bone; can evoke morphological lesions (e.g., erosion of caudal fin, spinal deformities); alters physiological function (e.g., enzyme inhibition, anemia, decreased survival); and impairs avoidance behavior (IPCS 1989). The report compiled by International Programme on Chemical Safety (IPCS 1989) also summarized studies on effects of lead on amphibians, which include arrested development and delayed hatching. Similarly, while their review was not focused solely on lead sources linked directly to hunting and fishing activities, Patte and Pain (2003) considered the literature about lead in the environment and identified many existing studies pertinent to this focus on lead exposures. For example, studies in the Coeur d'Alene floodplain, which is heavily contaminated by heavy metals such as arsenic, lead, and zinc from mining and smelting activities, have also detected negative effects from the accidental ingestion of lead-contaminated food or the accidental ingestion of lead associated with sediments in osprey (*Pandion haliaetus*), raptors, songbirds, and tundra swan (*Cygnus columbianus*; Henny 2003). These negative effects included inhibition of delta-aminolevulinic acid dehydratase involved in heme synthesis, elevated lead levels in blood and tissues, and weight loss. In addition, waterfowl die-offs have been reported from this area since the early 1900s. Humans exposed to lead have experienced similar negative effects to those described for fish and wildlife.

Due to their intended scope, the aforementioned studies do not investigate the effects of bioavailable lead from spent ammunition or from lost fishing tackle. Lead objects can dissolve under certain conditions, thereby contaminating soil, sediment, and vegetation, and resulting in exposure of biota via ingestion of soil, sediment, food, and water. Nevertheless, for bioavailable lead arising from ammunition and fishing tackle to have significant effects on biota at the organism- or population-level, the quantity of shot or tackle lost within a given area would have to be substantial.

LEAD EXPOSURE RELATED TO SHOOTING ACTIVITIES

The effects of spent lead shot and bullets on American wildlife has been recognized since the 1870s (Sanderson and Bellrose 1986), but it wasn't until the 1959 publication by Bellrose, "Lead poisoning as a mortality factor in waterfowl populations," that the widespread hazard of spent lead shot was fully appreciated. The availability of spent lead in a terrestrial setting is a function of the depth these particulates are located in soil or sediment. Several investigations have demonstrated that shot accumulates in most sediment near the surface and, thus, the total number of shot available can increase in density and availability over time (Pain 1992). In an aquatic setting, spent lead shot availability is affected by water depth and the depth that the shot is buried within the sediment. With the popularity of sport shooting (target, trap, and skeet shooting) and firearms training in the United States and elsewhere, an estimated 72,600,000 kg per year of lead is deposited at 9,000 shooting ranges (USEPA 2001). The amount of lead shot deposited in waterfowl hunting areas has been estimated to range from 125,970 to 5,000,000 shot per hectare (Bellrose 1959; Pain 1992, respectively). It is generally accepted that shot density in a field or wetland is directly related to hunting or shooting intensity.

Documentation of fish ingesting spent lead bullets or shot was not found. Also, evidence was not found that ingestion of lead shot and lead bullets by amphibians or reptiles is a widespread problem, and there is limited information documenting the incidence of lead shot, bullets, fragments, or fishing sinkers in the digestive system of these vertebrates. Lance et al. (2006) reported reproductive failure in captive American alligator (*Alligator mississippiensis*) that was potentially associated with lead exposure. These alligators were fed wild nutria (*Myocastor coypus*) meat contaminated with lead shot, and the alligators' eggs' yolk had a high lead concentration (Lance et al. 2006). Ingestion of lead shot was also observed in other farmed American alligators (Camus et al. 1998) and Australian crocodiles (*Crocodylus porosus*; Hammerton et al. 2003). In general, studies with sites in close proximity to shooting ranges have found elevated concentrations of lead in the tissues of amphibians and reptiles, which is thought to be due to ingestion of lead with water and food items (Pattee and Pain 2003).

Birds can ingest spent bullets, shot, or their fragments. Ingestion most likely occurs due to the bird mistaking these lead artifacts for food or grit material (Sanderson and Bellrose 1986; Scheuhammer and Norris 1995). Waterfowl have been documented to die from ingesting lead shotgun pellets deposited on the bottom of lakes, in marshes, and in fields. Often cited reviews addressing the effects of ingested shot on waterfowl include Bellrose (1959) and Sanderson and Bellrose (1986). Waterfowl may succumb after ingesting one or more lead pellets, as their bodies waste away over a period of several weeks—losing from 30 to 50% of their normal weight. Less frequently, a large number of shot are ingested, resulting in an acute form of lead poisoning, and the bird dies even though it still has a normal weight. In addition, the risk of spent shot to other upland species, including dove and quail, has long been recognized (Kendall et al. 1996). Raptors and other avian predators, as well as scavengers, may be exposed to lead from the consumption of shot pellets and bullet fragments embedded in tissues of dead or wounded animals (Pattee and Pain 2003) or from tissues discarded in gut piles (Fisher et al. 2006). For instance, vultures and condors appear highly susceptible to toxicity from ingesting small quantities of lead shot or bullets, as they are unable to regurgitate pellets from their gastrointestinal tracts (Eisler 1988). The presence of lead in California condor (*Gymnogyps californianus*) habitats in California and Arizona, in conjunction with their extreme sensitivity to lead toxicity, has been suggested as the primary threat to the continued existence of the species (Pattee et al. 1990; Meretsky et al. 2000). Recent evidence indicates that lead ammunition embedded in carcasses of hunted game and mammalian predators (coyotes, *Canis latrans*) or gut piles are the main sources of the lead accumulated by California condors (Church et al. 2006).

Ingestion of lead shot and bullets by humans, or the associated dust when casting ammunition has received considerable attention (reviewed by CPSB 2002). There are numerous case reports of accidental or purposeful (pica) ingestion of lead shot by humans in the medical literature (Gustavsson and Gerhardsson 2005). Ingestion of lead shot and bullets can cause lead intoxication, and depending on number and mass of fragments, lead lodged in certain but not all tissues can result in toxicity (Khan 2005). Accidental ingestion of ammunition by children has been documented (Durback et al. 1989). Furthermore, many sportsmen reloading rifle and pistol ammunition cast their own lead bullets, an activity particularly popular with black powder shooters, which exposes them to lead (Anonymous 2006).

The hazard that ingestion of lead pellets and bullets might pose to higher vertebrates is acknowledged, and in some instances already vulnerable populations (e.g., California condor) may become further at risk.

FISHING ACTIVITIES AND LEAD

Lead in the form of fishing lures, sinkers, lead core fishing line, downrigger cannonballs, and weights on a wide variety of fishing traps and nets can be introduced into the aquatic environment when a commercial fisher or recreational angler loses fishing gear due to accidental or intentional breakage. The amount of lead fishing tackle lost in the aquatic environment through recreational and commercial fishing activity is not accurately known. In studies based on angler interviews and actual detection of lost tackle along shorelines, the reported amount of lead fishing tackle lost varies, depending on the intensity of fishing pressure, the location of angling activity such as distance from the shoreline or boat, the type of aquatic habitat that may increase gear breakage and loss, and angler skill. Based on interviews, Radomski et al. (2006) reported average loss rates of 0.0127 lures per hour, 0.0081 large sinkers per hour, 0.0057 split shot sinkers per hour, 0.0247 jigs per hour, and 0.0257 hooks per hour; while Duerr (1999), assessing the amount of lead fishing tackle lost and detected along shorelines, estimated that there was from 0.0 to 0.01 sinkers per square meter in areas of low angling pressure and 0.47 sinkers per square meter in areas of high angling pressure. Some reports suggest that loss of lead fishing tackle in the aquatic environment can be substantial (e.g., Scheuhammer and Norris 1995).

Fish most frequently ingest, partially or wholly, fishing tackle when hooked. Whether the fishing tackle remains in the fish depends on whether the angler successfully lands the fish and whether the hook is too deeply ingested to safely remove it from the fish. The abandonment of fish hooks and associated fishing tackle may arise due to an angler breaking the line with a fish on, or leaving deeply set hooks in the fish to reduce injury (Cooke et al. 2001). Most reported mortality associated with fishing tackle is not related to the fish being exposed to the lead material used in the fishing tackle, but rather due to the extent of injury, blood loss, exposure to air, and exhaustion during handling to remove the hook (Cooke et al. 2001). Studies that related lead exposure from ingested lead sinkers and jigs or other tackle to the mortality of fish were not found. Nevertheless, given that it is commonly accepted that hooks and leaded jigs embedded in the mouths of fish will work their way loose, the effects of the lead from embedded fishing hooks and jigs would be minimal, in comparison to the potential sub-lethal and lethal injuries that may occur from swallowed hooks.

Evidence was not found that ingestion of lead fishing tackle by amphibians or reptiles is a widespread problem. There are published and unpublished accounts, however, of turtles suffering from lead poisoning after ingesting lead fishing weights (Borkowski 1997).

Concern about lead poisoning in birds from anglers' lead weights emerged as a significant issue during the 1970s as mute swan (*Cygnus olor*) populations declined in Britain (Sears 1988). This eventually resulted in the banning of most lead fishing sinkers in the United Kingdom in 1986 (Pattee and Pain 2003). In North America, the hazard of fishing sinkers and tackle to common loons (*Gavia immer*) was subsequently reported (Franson and Cliplef 1992; Pokras and Chafel 1992; Stone and Okoniewski 2001). Necropsy of common loons examined in New England found that lead poisoning from ingested fishing sinkers accounted for about one-half of the mortality in dead and moribund adults found during the breeding season (Pokras and Chafel 1992; Sidor et al. 2003). Birds most frequently ingest fishing tackle that has been lost or abandoned by anglers along the banks or within water-bodies. In their review, Scheuhammer and Norris (1995) stated that birds generally ingest lead fishing weights that are less than 57 grams (2 ounces), although ingestion of larger sinkers has been documented in the common loon (Franson et al. 2003). Thus, the harm from fishing weights to waterbirds seems to primarily involve smaller lead fishing weights used by recreational anglers (Scheuhammer and Norris 1995) and not larger weights or downrigger cannonballs. Based on the recovery of fishing weights associated with other fishing tackle (i.e., swivels and hooks), some birds such as the common loon may be ingesting lead fishing weights as a byproduct of ingesting the bait attached to the fishing tackle (Franson and Cliplef 1992; Stone and Okoniewski 2001). Once ingested by a bird, the lead object, if retained within the gizzard, will be ground down and, combined with the effect of the acidic conditions in the digestive tract, result in the lead being released and absorbed into the bird's tissues (IPCS 1989; Scheuhammer and Norris 1995; Nordic Council of Ministers 2003). It has been reported that lead fishing sinkers and jigs have contributed to lead poisoning mortalities in a number of aquatic birds, particularly mute swans, whooper swans (*Cygnus cygnus*), Canada geese (*Branta canadensis*), mallards (*Anas platyrhynchos*), brown pelicans (*Pelecanus occidentalis*), and common loons (Franson and Cliplef 1992; Pokras and Chafel 1992; Scheuhammer and Norris 1995; Stone and Okoniewski 2001; Franson et al. 2003). If the bird has the lead object embedded subcutaneously or intramuscularly, lead poisoning should not occur as the pH conditions in these tissues do not dissolve lead objects (De Francisco et al. 2003). There is the risk, however, of secondary poisoning by lead fishing weights for waterfowl predators, but studies linking lead poisoning of predators due to ingestion of a lead fishing weight lodged in their prey were not found in the literature.

Ingestion of lead sinkers or the dust associated with their manufacturing has been known to cause harm in humans. In sinker ingestion, the occurrence of lead toxicity depends on the amount of time that the object is retained within the stomach (Fergusson et al. 1997). If the lead object is retained in the stomach long enough for the object to be dissolved by the stomach acid, the lead will be absorbed while it is in the small intestine (Fergusson et al. 1997). Once the lead object is out of the stomach and in the small intestine it poses less of a potential hazard for lead toxicity (Fergusson et al. 1997). The U.S. Environmental Protection Agency (USEPA 1994) estimated that approximately 0.8 to 1.6 million people manufacture lead fishing weights in their homes for either personal use or for sale, representing approximately

30 to 35% of lead sinkers produced in the United States. Scheuhammer and Norris (1995) speculated that there is likely a similar "cottage industry" in Canada. Thus, the cottage-industry of melting lead and producing lead fishing tackle such as lead sinkers and jigs is a potential source of lead poisoning in humans through lead inhalation (USEPA 2004).

Lead fishing tackle, especially the smaller fishing weights and jigs that can be ingested, may be a source of lead poisoning for some species of waterbirds and can exert sub-lethal and lethal effects in the individual. Although of concern where waterbird populations are low or declining, the ingestion of lead sinkers has not been demonstrated to have wide-spread population-level effects. Nevertheless, the potential hazardous effect of lead on humans and aquatic ecosystem fauna lends support to an ongoing, general effort to reduce lead introduced into the environment by human activities.

ACTIONS TO REDUCE LEAD EXPOSURE

The desire to limit lead exposure in humans has resulted in several international conventions and treaties, as well as national restrictions to minimize environmental release of lead from anthropogenic activities including use of leaded gasoline, lead in paint, lead solder in tin cans for food storage, and lead shotgun pellets (Nordic Council of Ministers 2003). Scheuhammer and Norris (1995) provide a brief overview of restrictions placed by nations that are specific to the use of lead shot. These restrictions range from voluntary use of non-toxic shot for all wetland bird hunting in the United Kingdom, to nationwide restrictions on hunting migratory waterfowl species with lead shot in Canada and the United States, to an outright ban on the use of lead shot for all hunting and target shooting over water and agricultural lands in Denmark. A more recent example of this effort is the passing of the 2007 California Assembly Bill 821 "Ridley-Tree Condor Preservation Act" that requires the use of non-lead ammunition for hunting big game and coyotes in the range of the California condor in central and southern California (Center for Biological Diversity 2007).

The hazard of ingested lead fishing weights on aquatic and terrestrial fauna and humans has resulted in societal pressure to place restrictions on the sale and use of lead fishing weights. For instance, some nations, including Denmark, Canada, Great Britain, and the United States (partially summarized by Nordic Council of Ministers 2003), have begun to apply restrictions on the sale and use of lead fishing sinkers and jigs. In Canada the use of lead sinkers or jigs weighing less than 50 grams (1.76 ounces) in national parks and national wildlife areas is prohibited (Michael 2006). The use of lead tackle is also banned on some U.S. federal lands that have loon and swan populations (Michael 2006). In 1999, the U.S. Fish and Wildlife Service announced its intent to establish additional lead-free fishing areas by expanding the prohibition on certain fishing sinkers and jigs to more refuges used by loons (USFWS 1999); however, this has yet to be implemented. Some states, consisting of Maine, Massachusetts, New Hampshire, Vermont, and New York have, nonetheless, instituted restrictions on the use or sale of certain lead sinkers and jig heads (Michael 2006).

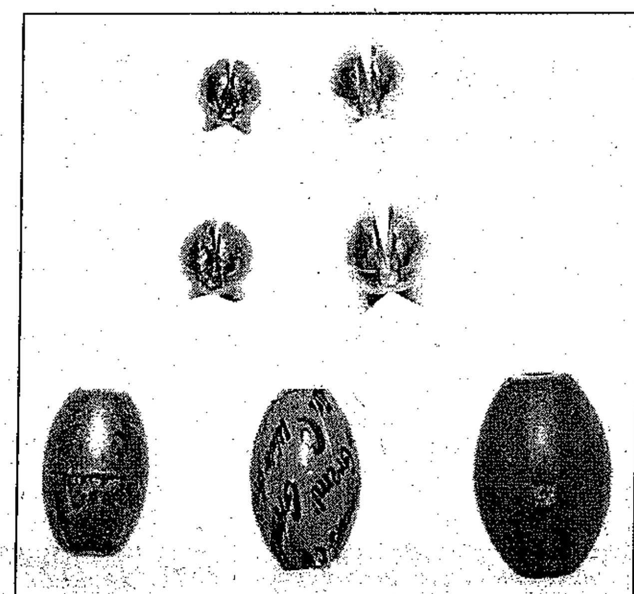


Figure 1. Relative sizes of sinkers manufactured from different materials.
Top row: 0.1 oz lead and tin split shot.
Middle row: 0.2 oz lead and tin split shot.
Bottom row: 0.8 oz lead, bismuth, and plastic-iron composite egg sinkers.
Sinkers courtesy of Water Gremlin.

T. Lawrence, GLFC

There are alternatives to lead bullets (e.g., copper; Barnes 2008) and to lead shot available to hunters. Alternatives to lead shot that have been approved for use in hunting waterfowl and coots and that are commercially available include shot made from steel, bismuth-tin, tungsten-bronze, tungsten-iron, tungsten-matrix, tungsten-nickel-iron, tungsten-polymer, tungsten-tin-bismuth, and tungsten-tin-iron-nickel. Substitutes for lead fishing tackle also have been available in retail stores in Canada, the United States, and European countries for several years (Scheuhammer and Norris 1995; Nordic Council of Ministers 2003). These include tungsten (both plastic composites and putty), stainless steel, carbon steel, tin, tin-bismuth, brass, ceramics, glass, and pewter (Scheuhammer and Norris 1995; Nordic Council of Ministers 2003; MOEA 2006). Sinkers made from alternative materials have been accepted to varying degrees, depending on their cost and how similar they are to lead tackle. Several of these alternatives such as ceramics and tin are not as dense as lead and, hence, need to be larger to produce the same weight (see Figure 1). Many anglers believe this increase in size is detrimental when inducing fish to bite. Other alternatives such as brass and steel, while somewhat larger in size, have been advertised as making more noise as they bump over the bottom, which is claimed to serve as an attractant to fish.

It needs to be stated, however, that a transition to alternative materials for sinkers provides significant challenges to the tackle manufacturing industry in terms of increased cost, availability of raw materials, and increased manufacturing costs, as well as the increased cost to anglers. The high cost of alternative raw materials may make the transition to non-lead sinkers more problematic now than several years ago. For example, tin is perhaps the most viable alternative for split shot sinkers and the manufacturing costs are similar to lead. The December 2007 price differential for the raw materials, however, is approximately $7.42 per pound for tin versus $1.15 for lead (MetalPrices.com 2007). As the specific gravity of tin is 7.2 versus 11.3 for lead, more tin is required to provide the same weight. Tin, therefore, is not only more costly, but also has performance drawbacks. Bismuth and tungsten currently cost $15/lb and $20/lb respectively. Moreover, tungsten is becoming essentially unavailable and has a high manufacturing cost. Brass may prove to be a less desirable alternative, because brass contains approximately 9% lead, as well as some zinc which could be problematic. Sintered steel, an alternative for non-split shot sinkers, has a specific gravity of less than 7 and it tends to rust in the tackle box. Although a variety of alternatives to lead sinkers have been proposed and investigated by the manufacturers of fishing tackle, it is not clear which alternatives will provide reasonable performance at reasonable cost.

As part of the effort to reduce the use of lead in fishing activities, some U.S. states, Environment Canada, and some U.S. and Canadian organizations are offering small-scale programs that exchange non-lead tackle for an angler's lead tackle (MOEA 2006). Educational campaigns also introduce anglers to non-lead substitutes and alert anglers to the toxicity of lead in the aquatic environment, with the aim of increasing angler use of non-toxic alternatives.

SUMMARY

The effects of ingested lead shot and bullets used in hunting and shooting sports activities are well documented. Principally, these include lead toxicosis and mortality of waterfowl and their predators (Pattee and Pain 2003). These impacts have resulted in restrictions on the use of lead shot and bullets, and subsequently regulations mandating the use of various non-toxic shot for species with habitats that coincide with waterfowl and condors. Studies assessing sub-lethal and lethal effects from lead shot ingestion among other wildlife, such as upland birds, are being conducted and discussions regarding the implications of lead toxicosis are ongoing among managers and policy makers (e.g. Association of Fish and Wildlife Agencies' Non-toxic Ammunition Task Force and its Ad Hoc Mourning Dove and Lead Toxicosis Working Group).

Fishing tackle, especially weights that fall within the size usually ingested by fauna (e.g., less than 2.5 cm, 0.98 inches) and weighing less than 50 g (1.76 ounces; Scheuhammer and Norris 1995), can have lethal and sub-lethal effects on aquatic fauna and on humans when ingested. Downrigger weights (cannonballs), lead core fishing line, and the weights used on a variety of commercial traps and nets are much larger than fishing sinkers and smaller jigs that have been ingested by fauna in aquatic ecosystem and by humans. Therefore, one would predict that the effect normally associated with ingestion of lead fishing tackle is minimal for downrigger cannonballs, lead core fishing line, and the weights affixed to commercial fishing gear. Some studies have examined the dissolution of lead from fishing tackle, although these are few and not conclusive. More research needs to be conducted to determine the potential effect on fauna of the dissolution of all types of lead fishing tackle in low and high deposition densities and varying water chemistry conditions.

RECOMMENDATIONS

As stewards of North America's aquatic ecosystems, fisheries management agencies, anglers, angling clubs, and commercial fishers, as well as manufacturers and retailers of fishing tackle, work actively and often collectively for the protection and conservation of North America's aquatic ecosystems. A tenet of this stewardship is minimizing the introduction of toxic materials, such as lead, to levels that have been shown to be non-hazardous, while recognizing that complete elimination may be neither feasible nor necessary. Detrimental effects at the population level of bird species that ingest lead sinkers have not been documented in North America, but impacts at the population level should not be a prerequisite for corrective action. Current knowledge indicates that small lead (and other toxic) sinkers (< 2.5 cm), in particular, are most likely to be ingested by waterbirds. Several options exist for the American Fisheries Society (AFS), perhaps through a small task group, to develop a position statement (white paper) based on the scientific data on the hazard and risk of lead from lost commercial and recreational fishing tackle.

1. The AFS could work with the provincial, state, and federal fisheries management agencies, in addition to the angling clubs, tackle manufacturers, and tackle retailers to educate anglers and commercial fishers about the availability and utility of non-toxic alternatives to lead weights and the environmental benefits of using these alternatives. AFS could also work with the U.S. National Institute of Health and Health Canada to educate anglers about the potential health hazards of casting and manufacturing their own lead sinkers and jigs.
2. The AFS Fisheries Management and Fisheries Administration Sections could collaborate to develop a specific Aquatic Resources Conservation Electronic Library (ARCeL) module for use as part of a lead-free education/outreach project, perhaps funded by the Fisheries Conservation Foundation. All of the requisite educational materials could be made available for production and distribution by all management agencies, fishing tackle manufacturers, and retailers.
3. AFS could partner with and encourage fisheries management agencies to develop lead tackle exchange programs and, in conjunction with this tackle exchange effort, participate in safe collection and disposal programs for lead fishing tackle.
4. AFS could work closely with the Association of Fish and Wildlife Agencies (AFWA), fishing tackle manufacturers, the American Sportfishing Association (ASA), and the Canadian Sportfishing Industry Association (CSIA) to encourage and facilitate a transition from the manufacture, distribution, and sale of small lead fishing weights to fishing weights made of non-toxic alternative materials. The development of schedules would facilitate this transition. It is recognized that a number of the recreational and commercial fishing tackle manufacturers have already taken the initiative by entering into the lead-free tackle market, and are well into this transition; however, the shelf space and volume of alternate material weights remains a small percentage of the overall inventory and sale of these small fishing weights
5. Consistent with the above negotiated transition schedule for the manufacture and sale of alternatives to lead, the AFS could work with the AFWA, ASA, and CSIA to develop a framework for future phased-in regulations on the sale, use, and possession of lead fishing sinkers while fishing. This framework would provide for requisite consistency in the rules, regulations, and their implementation; would help deliver a strong message to anglers; and would allow manufacturers to more easily develop and market non-lead products.
6. The AFS may consider local bans on the use of lead fishing sinkers as an appropriate management tactic in geographical areas of high annual mortality of waterbirds associated with lead poisoning and in heavily protected pristine areas such as national parks and national wildlife refuges.

In conclusion, AFS interacts with many natural resource management agencies, angling organizations, and the fishing tackle industry. AFS, therefore, is in a position to both foster education on the hazards of lead to wildlife and to develop a position statement with the aim of reducing to an absolute minimum the introduction of lead into the aquatic environment from fishing activities.

REFERENCES

Anonymous. 2006. Recommendations for reducing exposure. MidwayUSA Master Catalogue, page 175. Columbia, Missouri. Available at: www.midwayusa.com/static.exe/getstaticpage?page=lead_warning.htm (December 2006).

Barnes Bullets. 2008. Barnes Bullets—the future in bullet technology! Barnes Bullets, American Fork, Utah. Available at www.barnesbullets.com/ (March 2008).

Bellrose, F. C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Natural History Survey Bulletin 27:235-288.

Borkowski, R. 1997. Lead poisoning and internal perforations in a snapping turtle (*Chelydra serpentina*) due to fishing gear ingestion. Journal of Zoo and Wildlife Medicine 28(1):109-113.

Braun, J. M., R. S. Kahn, T. Froelich, P. Auinger, and B. Lamphear. 2006. Exposures to environmental toxicants and attention deficit hyperactivity disorder in U.S. children. Environmental Health Perspectives 114(12):1904-1909. Available at: www.ehponline.org/members/2006/9478/9478.pdf. (July 2007).

Camus, A. C., M. M. Mitchell, J. F. Williams, and P. L. H. Jowett. 1998. Elevated lead levels in farmed American alligators *Alligator mississippiensis* consuming *Myocastor coypus* meat contaminated by lead bullets. Journal of World Aquaculture Society 29:370-376.

Center for Biological Diversity. 2007. Schwarzenegger approves historic condor protection bill. Center for Biological Diversity, Tucson, Arizona. Available at: www.biologicaldiversity.org/swcbd/press/condor-lead-10-13-2007.html (November 2007).

Church, M. E., R. Gwiazda, R. W. Risebrough, K. Sorenson, C. P. Chamberlain, S. Farry, W. Heinrich, B. A. Rideout, and D. R. Smith. 2006.

Ammunition is the principal source of lead accumulated by California condors re-introduced to the wild. Environmental Science and Technology 40:6143-6150.

Coa, X., L. Q. Ma, M. Chen, D. W. Hardison Jr., and W. G. Harris. 2003. Weathering of lead bullets and their environmental effects at outdoor shooting ranges. Journal of Environmental Quality 32:526-534.

Cooke, S. J., D. P. Philipp, K. M. Dunmall, and J. F. Schreer. 2001. The influence of terminal tackle on injury, handling time, and cardiac disturbance of rock bass. North American Journal of Fisheries Management 21:333-342.

CPSB (Consumer Product Safety Bureau). 2002. Lead risk reduction strategy, draft. Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. Available at: www.hc-sc.gc.ca/cps-spc/pubs/cons/lead-plomb/index_e.htm. (February 2007).

De Francisco, N., J. D. Ruiz Troya, and E. I. Agüera. 2003. Lead and lead toxicity in domestic and free living birds. Avian Pathology 32:3-13.

Duerr, A. E. 1999. Abundance of lost and discarded fishing tackle and implications for waterbird populations in the United States. Master's thesis. School of Renewable Natural Resources, University of Arizona, Tucson.

Durback, L. F., G. P. Wedin, and D. E. Seidler. 1989. Management of lead foreign body ingestion. Clinical Toxicology 27(3):173-182

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center. Contaminant Hazard Reviews Report 14, Biological Report 85(1.14). U.S. Fish and Wildlife Service, Laurel, Maryland.

Fergusson, J., G. Malecky, and E. Simpson. 1997. Lead foreign body ingestion in children. Journal of Paediatrics and Child Health 33:542-544.

Fisher, I. J., D. J. Pain, and V. G. Thomas. 2006. A review of lead poisoning from ammunition sources in terrestrial birds. Biological Conservation 131:421-432.

Franson, J. C., and D. J. Cliplef. 1992. Causes of mortality in common loons. Pages 2-59 *in* L. Morse, S. Stockwell, and M. Pokras, eds. Proceedings from the 1992 Conference on the Loon and its Ecosystem: Status, Management, and Environmental Concerns, 22-24 August 1992, College of the Atlantic, Bar Harbor, Maine.

Franson, J. C., S. P. Hansen, T. E. Creekmore, C. J. Brand, D. C. Evers, A. E. Duerr, and S. DeStefano. 2003. Lead fishing weights and other fishing tackle in selected waterbirds. Waterbirds 26:345-352.

Gustavsson, P., and L. Gerhardsson. 2005. Intoxication from accidentally ingested lead shot retained in the gastrointestinal tract. Environmental Health Perspectives 113:491-493.

Hammerton, K. M., N. Jayasinghe, R. A. Jeffree, and R. P. Lim. 2003. Experimental study of blood lead kinetics in estuarine crocodiles (*Crocodylus porosus*) exposed to ingested lead shot. Archives of Environmental Contamination and Toxicology 45:390-398.

Henny, C. J. 2003. Effects of mining lead on birds: a case history at Coeur d'Alene Basin, Idaho. Pages 755-766 *in* D. J. Hoffman, B. A. Rattner, G. A. Burton, and J. Cairns Jr., eds. Handbook of ecotoxicology, 2nd edition. Lewis Publishing Inc., Boca Raton, Florida.

Henny, C. J., L. J. Blus, D. J. Hoffman, and R. A. Grove. 1994. Lead in hawks, falcons, and owls downstream from a mining site on the Coeur d'Alene River, Idaho. Environmental Monitoring and Assessment 29:267-288.

Hernberg, S. 2000. Lead poisoning in a historical perspective. American Journal of Industrial Medicine 38:244-254.

Hui, C. A. 2002. Lead distribution throughout soil, flora and an invertebrate at a wetland skeet range. Journal of Toxicology and Environmental Health 65:1093-1107.

IPCS (International Programme on Chemical Safety). 1989. Lead environmental aspects. Environmental Health Criteria 85. World Health Organization, International Programme on Chemical Safety (IPCS), Geneva, Switzerland.

Jacks, G., and M. Bystrom. 1995. Dissolution of lead weights lost when fishing. Division of Land and Water Resources, Royal Institute of Technology, Stockholm.

Kendall, R. J., T. E. Lacher Jr., C. Bunck, F. B. Daniel, C. Driver, C. E. Grue, F. Leighton, W. Stansley, P. G. Watanabe, and M. Whitworth. 1996. An ecological risk assessment of lead shot exposure in non-waterfowl avian species: upland game birds and raptors. Environmental Toxicology and Chemistry 15:4-20.

Khan, A. N. 2005. Lead poisoning. eMedicine instant access to the minds of medicine. Available at: www.emedicine.com/radio/topic386.htm (October 2005).

Lance, V. A., T. R. Horn, R. M. Elsey, and A. dePeyster. 2006. Chronic incidental lead ingestion in a group of captive-reared alligators (*Alligator mississipiensis*): possible contribution to reproductive failure. Comparative Biochemical Physiology C 142:30-35.

Meretsky V. J., N. F. Synder, S. R. Beissinger, D. A. Clendenen, and J. W. Wiley. 2000. Demography of the California condor: implications for reestablishment. Conservation Biology 14: 957-967.

MetalPrices.com. 2007. Metal prices and news on the Internet. Basalt, Colorado. Available at: www.metalprices.com/ (December 2007).

Michael, P. 2006. Fish and wildlife issues related to the use of lead fishing gear. Washington Department of Fish and Wildlife Fish Program, FPT 06-13. Available at: http://wdfw.wa.gov/fish/papers/lead_fishing_gear/fpt_06-13.pdf (July 2007).

MOEA (Minnesota Office of Environmental Assistance). 2006. Let's get the lead out! Non-lead alternatives for fishing tackle. Minnesota Pollution Control Agency, St. Paul. Available at: www.pca.state.mn.us/oea/reduce/sinkers.cfm (December 2006).

Needleman, H. L. 2004. Lead poisoning. Annual Review of Medicine 55:209-222.

Nordic Council of Ministers. 2003. Lead review. Nordic Council of Ministers Report 1, Issue 4. Nordic Council of Ministers, Copenhaven, Denmark. Available at: www.norden.org/pub/miljo/miljo/sk/US20031308.pdf (December 2006).

Pain, D. 1992. Lead poisoning in waterfowl. Proceedings of the International Waterfowl and Wetlands Research Bureau, Slimbridge, Gloucester, U.K.

Pattee, O. H., P. H. Bloom, J. M. Scott, and M. R. Smith. 1990. Lead hazards within the range of the California condor. Condor 92:931-937.

Pattee, O. H., and D. J. Pain. 2003. Lead in the environment. Pages 373-408 *in* D. J. Hoffman, B. A. Rattner, G. A. Burton, and J. Cairns Jr., eds. 2008. Handbook of ecotoxicology, 2nd edition. Lewis Publishing Inc., Boca Raton, Florida.

Pokras, M. A. and R. Chafel. 1992. Lead toxicosis from ingested fishing sinkers in adult common loons (*Gavia immer*) in New England. Journal of Zoo and Wildlife Medicine 23:92-97.

Radomski, P., T. Heinrich, T. S. Jones, P. Rivers, and P. Talmage. 2006. Estimates of tackle loss for five Minnesota walleye fisheries. North American Journal of Fisheries Management 26:206-212.

Rattner, B. A., J. C. Franson, S. R. Sheffield, C. I. Goddard, N. J. Leonard, D. Stang, and P. J. Wingate. 2008. Sources and implications of lead ammunition and fishing tackle on natural resources. The Wildlife Society Technical Review, in press.

Rooney, C. P., R. G. McLaren, and R. J. Cresswell. 1999. Distribution and phytoavailability of lead in a soil contaminated with lead shot. Water, Air, and Soil Pollution 116:535-548.

SAAMI (Sporting Arms and Ammunition Manufacturers' Institute, Inc.). 1996. Lead mobility at shooting ranges. Catalog Number FD-1/708. National Shooting Sports Foundation, Inc., Newtown, Connecticut.

Sanderson, G. C., and F. C. Bellrose. 1986. A review of the problem of lead poisoning in waterfowl. Illinois Natural History Survey Special Publication 4.

Scheuhammer, A. M., and S. L. Norris. 1995. A review of the environmental impacts of lead shotshells ammunition and lead fishing weights in Canada. Canadian Wildlife Service Occasional Paper 88, Environment Canada, Ottawa, Ontario.

Sears, J. 1988. Regional and seasonal variations in lead poisoning in mute swan *Cygnus olor* in relation to the distribution of lead and lead weights in the Thames area, England. Biological Conservation 46:115-134.

Sidor, I. F., M. A. Pokras, A. R. Major, R. H. Poppenga, K. M. Taylor, and R. M. Miconi. 2003. Mortality of common loons in New England, 1987 to 2000. Journal of Wildlife Diseases 39:306-315.

Stone, W. B., and J. C. Okoniewski. 2001. Necropsy findings and environmental contaminants in common loons from New York. Journal of Wildlife Diseases 37(1):178-184.

USEPA (U.S. Environmental Protection Agency). 1994. Lead fishing sinkers; response to citizens' petition and proposed ban; proposed rule. Federal Register Part III, Volume 40, Part 745:11121–11143.

____. 2001. Best management practices for lead at outdoor shooting ranges, EPA-902-B-01-001. USEPA, Division of Enforcement and Compliance Assistance, RCRA Compliance Branch, New York. Available at: www.epa.gov/region02/waste/leadshot/epa_bmp.pdf (March 2007).

____. 2004. Humans and lead fishing sinkers. USEPA Office of Water, Washington, DC. Available at: www.epa.gov/owow-wtr1/fish/humans.html (September 2005).

USFWS (U.S. Fish and Wildlife Service). 1999. Establishing "lead free fishing areas" and the prohibition of the use of certain fishing sinkers and jigs made with lead on specific units of the National Wildlife Refuge system. 50 CFR Part 32, Federal Register 64:17992.